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Mass Storage Systems and Technologies
for Space and Earth Science Applications

ATL Products Division's Entries Into the Computer Mass Storage Marketplace

July 24, 1991

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ATL Products Division

Odetics

Odetics Background

- High Tech Company Founded in 1969, Publicly Traded
  - Serving Well-Defined Niche Markets
  - Through Variety of Product Groups
- Roots are in Space Borne Recorders
  - Own 80% of Marketplace
- Evolved Into Robotics in Mid-70s
  - AIM, Broadcast, DMS, ATL Products Divisions
  - 35% of Revenues and Growing
  - Technology and People Move From One Division to Another

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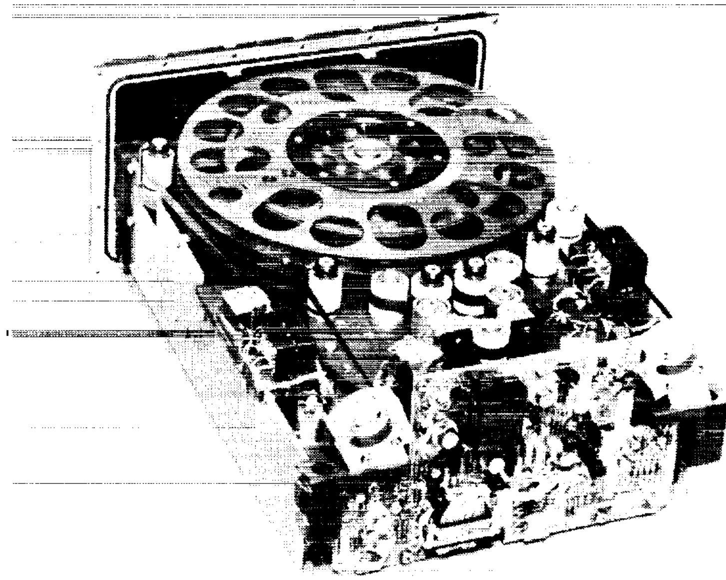
Spaceborne Tape Recorder



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ATL Products Division
Odetics

Product Evolution

- Robotics Genesis - AIM
- Company's High Technology Group
  - 1979 Committed to a Six Legged Robotic System
  - 18 Months Later Demonstrated ODEX I
    - Symbol of the Corporate Commitment to Robotics
  - Demonstrates High Strength to Weight Ratios
  - All Electric, Compact, Extremely High Performance
  - Six Units Built - Three Generations of Technology
    - Predominantly for Nuclear Plant Maintenance
- Evolution to Other Robotic Subsystems
  - Arms, Hands, and Effectors
-

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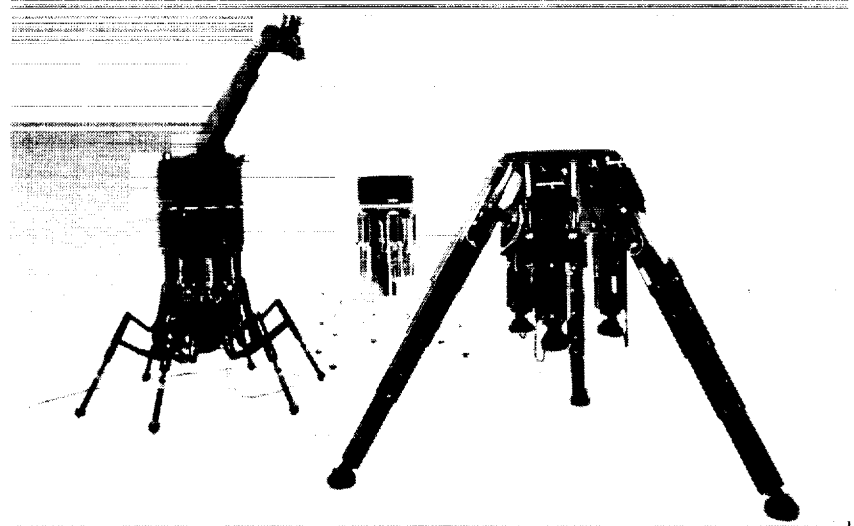
Three Generations of ODEX



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ATL Products Division
Odetics

Product Evolution
Technologies and Markets Served

- **Innovators In "Small Package" Handling**
- **Do Not Serve General Purpose Robotics Handling Market**
- **Design Intent of Our Products**
  - Move "Small Light Weight Objects" Very Quickly
  - Accent On Longevity of "Object" Being Moved
  - High Degree of Reliability
- **Necessitates**
  - Expertise in Low Mass, Light Weight, High Speed Systems
  - Requires Unique Robotic Handlers, Arms, End Effectors
  - Products Designed for Niche Markets
    - Aperture Card Storage Module Systems
    - Tape Cassettes and Cartridges
    - Optical Disks

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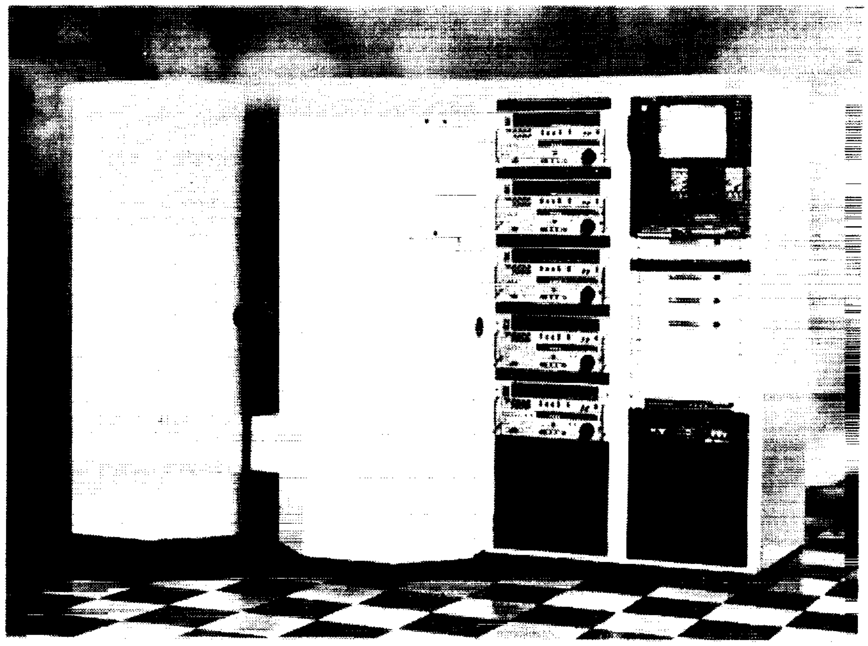
Product Evolution
Infodetics' Aperture Storage Module Library

- **First Linear Servo Based Expandable System**
- **Modules: 10 Ft. Long By 3 Ft. Deep By 7 Ft. High**
  - 2000 Cartridges Per Two Rows or Module
  - 100 Aperture Cards Per Cartridge
  - Robotic Handler in Aisle Between Rows Within Module
- **Large System With Multiple Modules and Pass-Through**
- **5 Seconds Average "Pick and Place"**
  - Access Cartridge and Load Into Aperture Card Reader
- **Document Management System "Storage Server"**
  - Cache Microfilm Images to Disk
  - Transmitted to Work Stations for Viewing

Product Evolution
Broadcast Division's TCS2000 Video Cart

- **First "Tower" Based Expandable System Introduced '86**
  - Designed as a TV Station or Network Automation System
- **Built as Part of a Joint Venture With RCA in 18 Months**
  - RCA Dropped Out, Odetics Entered End User Market
- **System Consists of:**
  - Robotics and Up to 6 Tape Recorders Per Tower
  - 225 to 300 Tapes Per Tower Depending On Formats
  - Switchers, Sequencers, Monitor and PC Based Work Station
  - Hierarchical Software
    - Real-Time Controller/Operating System, Relational DB, Playlist
- **Supports VHS, Beta, D-2 Formats**
- **Robust, Redundant and Extremely Reliable**

TCS2000 Cart Machine With Library Expansion Module



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Broadcast Division's Newest Product
TCS90 Videocart System

- **Bookshelf Design**
  - X-Y High Speed Linear Servo System
  - One Armed Gripper With Holding Tray
- **Accommodates Combination of Cassette Sizes and Format**
  - Beta SP, VHS, or D-2
  - Small and Medium Sizes
- **Tape Recorders are Standard: Non-Modified**
- **Autoloader Accommodates Up to 8 Cassettes**
- **Fixed Size**
  - No Expansion Capabilities
- **Software From TCS2000 Migrates Directly to This Product**
  - 50 Man Years of Development

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TCS90 Cart Machine

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ATL Products Division
Marketing Strategy

- **Serve the Evolving Computer Based Mass Storage Market**
- **Develop Library Automation Subsystems**
  - Robotics, Control, Storage and Computer Interfaces
  - Support a Broad Range of Tape Sizes and Formats
  - Interface to a Variety of Tape Drives in Each Size
  - Provide Low Level Library Control and Management Software
- **Sell Through Distribution Channels That:**
  - Integrate Tape Drives
  - Add High Level Mass Storage Management Software
  - Service a Broad Range of User Markets
  - Provide "Private Labelled" and "General Purpose" Products
- **Pursue Major Market Shares**
  - High Density/High Capacity Storage Market
  - General Commercial Market By Supplying a Range of Solutions

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ATL Products Division
Odetics

High Density Systems Business
Product Lines

- **Developing Two Basic 19mm ATL Storage Subsystems**
  - To Serve High Capacity Markets: Terabytes and Petabytes
  - Support Small and Medium Size D-2 Cassettes
- **Expandable "Tower" Based System**
  - Broadcast System as Platform
  - Auxiliary Towers for Expansion
  - Delivered March, 1991
- **New Linear Aisle Based Expandable System**
  - 30 Months in Development: Delivery August, 1991
  - Most Advanced Robotic System On the Market

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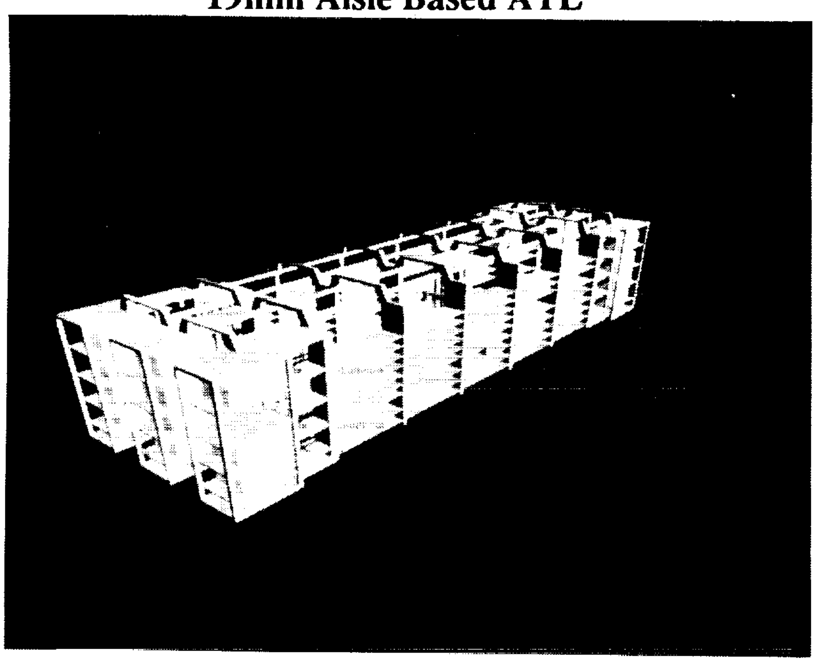
19mm Aisle Based ATL



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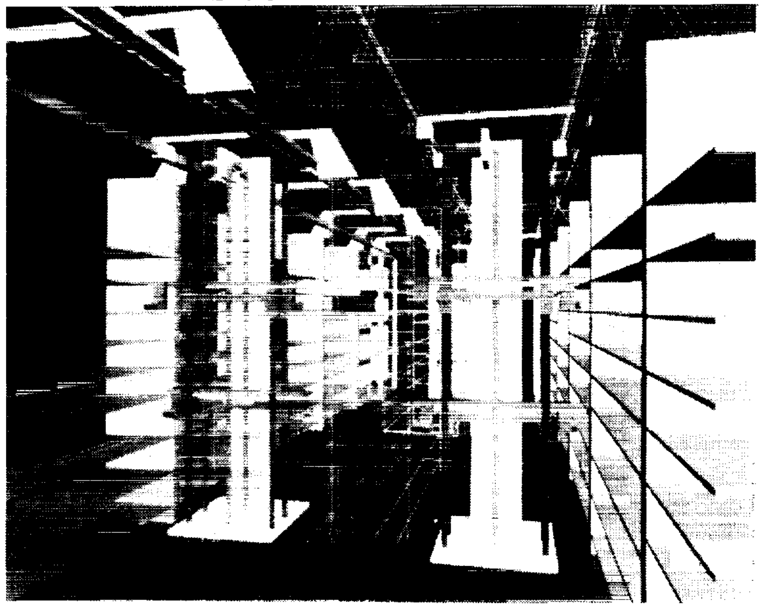
19mm ATL Cut Away
Side View of Robots



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High Density Systems Business
Product Lines

- **10 Minute Video On Two Technologies**
  - Copies of Video Available Upon Request
  - Text of Narration Follows Presentation

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ATL Products Division
Odetics

E-Systems Business Relationship

- **Exclusive Supplier of 19mm ATL Subsystems**
  - Computer Mass Storage Marketplace Only
- **Can Market Other Odetics ATL Subsystems**
- **E-Systems Is the Integrator**
  - Providing Systems Expertise - ATLs, Tape Drives, Computer Integration
  - Library Management Software for the ATLs
  - Supplying Storage Server Software

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ATL Products Division
Odetics

3480 "Medium Size" Library
First Commercial Product Offering

- **"300" Cartridge Baseline System**
  - Expandable in Increments of Approximately 300 Cartridges
  - "1500" Cartridge Maximum
- **Up to 2 Tape Drives Available In Baseline**
  - Up to 4 Additional Drives as System Expands
  - Supports All Low Cost 3480 Tape Drives
- **Small Footprint**
  - Fits Standard 28 Inches Wide By 45 Inches Deep By 78 Inches High Cabinet
  - Very High Density Storage
- **Cartridge Autoloader and Bulk Loading**
- **RS-232C or SCSI-II Interface**
- **Serve the Distributed Computing and File Server Markets**

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ATL Products Division
Odetics

Storage and Library Management

- **ATLs are Driven With "Low Level" Commands**
  - Pick From Bin and Move to Tape Drive
  - Status Provided Back Through Sensors
  - Electrical Interface: RS-232C, Ethernet, SCSI-II
  - New Software Interface: SCSI-II, Chapter 16 Jukebox Commands
- **Library Management: Physical Volume Repository**
  - Input PVS and Provide Level of Intelligence
  - Management Resource and Allocation of Bins and Drives
  - Automatic Error Recovery
- **Servers and Applications Provide Next Level**
  - Storage Servers and Bit File/Client Servers
  - Backup

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ATL Products Division
Odetics

Summary
What Odetics Can Offer the Market

- **We Are and Will Be a Major Supplier of Robotic Libraries**
  - Advancing Technologies
- **By Year End, From Broadcast and ATL Products Divisions**
  - Four Different ATL Technologies and Five Products
  - Cross "Breeding" of Technologies Across Divisions
- **In the Future**
  - Broader Reach of Products and Markets Using Robotics
  - Further Transfer of Technologies at Component Levels

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ATL Products Division
Odetics

ATL PRODUCTS VIDEO

19mm High Density Tower & Aisle Technologies

Narration

- The information explosion is here. The amount of data being collected is growing at an ever increasing pace. As a result, the task of managing that data presents new challenges for data processing professionals.
- How do you effectively manage your data while providing rapid availability to your users, reduce costs for labor and storage, eliminate misplaced tapes and ensure security?
- Odetics, a leader in robotic storage and retrieval systems has a solution for you. A variety of automated tape library, or ATL systems are being developed for use in a broad range of applications.
- A culmination of twenty years experience, these ATL products will utilize robotic technologies found in hundreds of installed, field-proven aperture card information and broadcast video cart systems.
- This presentation introduces two of our mass storage subsystems -- We'll start with the aisle-based automated tape library from Odetics.
- This expandable automated tape cassette library represents the highest density mass storage subsystem available. It's capable of storing terabytes or even petabytes of data. This system was specifically designed to meet the needs of the federal government which is the largest user of data in the United States.
- Its unique architecture moves tapes through the library rapidly and efficiently. And it's completely modular. As a result, it can easily be configured to meet your specific floor plan requirements while maximizing storage density and the system can be easily expanded to keep pace with your growing requirements.
- This animation utilizes a combination of solid and wire-frame images. The outer skins of the system have been removed to provide the best perspective of the ATL in operation.
- For this presentation, a system configuration of 2 aisles and 3 rows is shown.
- Small 25 gigabyte and medium sized 75 gigabyte 19mm D-2 cassettes are stored vertically in the library. Each medium D-2 cassette has the same storage capacity as 520 reels of 9 track, 6250 bpi magnetic tape.
- The cassettes are kept in rows of modular bins called cassette storage modules.
- These modules can be joined to form rows up to 80 feet in length.
- Robots operate in the aisles between the rows. They move cassettes between bins and tape drives located at either end of the library.
- Maximum speeds are nine feet per second in the horizontal axis and 2 feet per second in the vertical.
- The robots are gantry-based. They travel on tracks mounted along the top of each row of storage bins.
- As a result, there's sufficient clearance between the robot and the floor to protect any cassettes which might inadvertently fall from a bin.

- A network of sensors can halt the robot within a half second in response to any object that would interfere with its movement.
- Each robot is controlled by electronics which interfaces with the system's host computer through an Ethernet Local Area Network. Commands to move the robot are sent from the host to the control electronics which are not shown in this presentation.
- Servo drive electronics power the robot's components.
- Each robot has two tape accessors which consist of a sliding arm and a uniquely designed gripper which can grip the different sized cassettes.
- The arms and grippers enable the robot to move cassettes to and from cassette storage modules on either side of the aisle.
- The two accessors are linked to one another by a belt which controls their vertical movement.
- A barcode scanner is mounted on the accessor arm. This scanner reads the barcode on the cassette to verify its identity prior to removing it from the bin.
- Up to four tape drives are housed in a recorder mounting module stacked vertically in compartments. The end unit houses a corresponding number of cassette loader modules which move tapes between the robots and the tape drive.
- The robot places a cassette in the bin on the platform of the cassette loader module.
- Since tape drives can be positioned on both ends of the system, facing inward, the platforms on one end, in this case, the left rotate 180 degrees to position cassettes properly for placement in the drive.
- The bin is mounted on a vertical slide that lifts the cassette to where it's engaged by a gripper.
- The gripper swings the cassette 90 degrees into the horizontal position and inserts the cassette into the tape drive.
- For library management, a bulk loader for loading and unloading up to 10 cassettes from the library at a time is also provided. Although they're not shown in this presentation, the bulk loader and the control electronics each replace a tape drive and cassette loader module in an end unit.
- Lets watch the subsystem operate at actual speed as we summarize its key features.
- As you have seen, the ATL is extremely versatile and redundant. Cassettes can be accessed by either of two robots.
- Performance and efficiency are exceptional. Maximum time to do a cassette pick and place from one end of an 80 feet row to the other, including tape drive insertion, takes less than 23 seconds.
- The ATL is completely modular. Components can be arranged in combinations that fit any floor plan.
- It's also expandable. Rows and aisles can be added to the library without interrupting operation. A user can start with a small system and as storage requirements grow, it can be easily expanded over time.
- Finally, the system architecture is reliable. Redundancy built into the system provides maximum uptime. And individual components are designed to last.

- Another application of our mass storage technology, the TCS2000 Odetics Broadcast Videocart Machine, has established a new industry standard for efficiency and economy in playing both television station and network programming and commercials to air.
- In the system's tower, robotics control the programs and commercials which are recorded on 1/2" analog VHS, Beta or 19mm D-2 videocassettes.
- These cassettes are stored in up to 280 bins within the storage tower.
- A 4 armed robot moves the cassettes from the bins to tape drives which are stacked in the rear.
- There is a variety of other hardware including video switchers and monitors as well as a menu driven interactive touch panel which is used to make changes to the play list rapidly and without mistakes.
- A powerful microcomputer controls the system.
- Commands are sent from the playlist to a sequencer which manages the robotics and controls the tape drive electronics so events are played to air in the correct order.
- Software maintains a database of up to 65,000 commercials and program segments on cassettes stored inside and outside the tower.
- With over 50 man years of development, the software also has a myriad of user oriented features for on-line editing of playlists that make the TCS2000 not only easy to use but allows error-free operation.
- Over 130 TCS2000 systems are installed worldwide, and it has become the broadcast industry standard for videocarts.
- It's proven to be a highly effective solution that reduces costs and dramatically improves accuracy and efficiency.
- And now, the tower technology has been adapted to serve as an automated tape library for mass storage of computer data. And users can expect the same outstanding results.
- With high density digital D-2 cassettes, the tower has the capacity to achive 5.7 terabytes of data.
- This makes the tower ATL a more cost-effective storage alternative than magnetic storage or even optical disks for "near" line storage.
- It can store up to 227 small D-2 cassettes with each cassette storing 25 gigabytes of data. That's equal to the capacity of 175 9 track 6250 bits per inch magnetic tapes.
- Like the broadcast system, an automatic cassette loader, mounted in the door, allows up to ten cassettes to be loaded or removed from the library quickly and easily.
- As cassettes enter or exit through the autoloader, a barcode reader scans their barcode labels. The information is automatically entered into a database residing in host computer software which tracks cassettes and generates reports on usage.
- The drive electronics, mounted in the rear of the tower, accept pick and place commands which direct the robot to the proper bin and tape drive locations as it moves cassettes through the system.

- The rapid vertical movement of the 4 armed robot is controlled by a digital stepping motor mounted at its base, geared to a nylon belt.
- Each of the four arms includes a custom-designed, highly reliable end effector which grips the cassette with a controlled force to protect it from damage.
- The cassette loader module is the transport mechanism that passes cassettes between the robot and its corresponding tape drive.
- Once the cassette reaches the loader module, the robot places the cassette into the module's input port. The cassette then moves along a conveyor which is aligned to the throat of the drive.
- These tape drives are mounted in a recorder mounting module at the rear of the tower.
- When unloading, cassettes move through the cassette loader module to the robot arm in a similar manner.
- Simple cassette pick and place commands are transmitted through an RS232C hardware interface.
- The maximum time for moving a cassette from its storage bin to a tape drive is less than 7 seconds.
- As with the broadcast system, the robotics are extremely reliable. With over 200 man years of maintenance logged on TCS2000 systems in the field, it has a proven record of 99.999 percent availability. As a result, the system has dramatically improved the efficiency and accuracy of broadcast play to air operations for our customers. That means significantly lower costs and greater profitability. And data storage users can expect similar benefits.
- The modular tower design facilitates ease of maintenance. The entire robot can be quickly removed and replaced in a maximum of 30 minutes.
- And like the TCS2000, the system is easily expanded.
- Up to six towers can be linked together via a specially designed mobile storage bin which transfers cassettes between units within six seconds. Now, user's have an extremely cost-effective means of increasing capacity as storage needs expand.
- As companies grow, the problem of finding an efficient, reliable, cost-effective means of archiving large quantities of digital data becomes more and more challenging.
- The mass storage systems manufactured by Odetics meet these challenges by providing longer hours of reliable operation, with significantly improved efficiency, improved security and lower costs.
- Their proven technology and intelligent, modular design make them easily adapted to meet your archiving needs.
- As with all of our automated storage systems, Odetics developed these two powerful technologies to solve your company's data explosion by providing the easiest, most productive and cost-effective means of managing and utilizing large quantities of data.

PANEL DISCUSSION:
STABILITY OF HIGH DENSITY MAGNETIC TAPE

Moderator: Professor Mark Kryder

Participants: Bellcore, Ampex, Sony, Advanced Development Corp., NML-3M

MR. SAVAGE: We have come to the panel section of the afternoon session. Our panel moderator this afternoon is Professor Mark Kryder from Carnegie Mellon University in Pittsburgh, Pennsylvania. Mark has a respectable biography here, which I think I will read because they are still making a few preparations there.

Mark received a B.S. Degree in Electrical Engineering from Stanford in 1965, an M.S. in Electrical Engineering from Cal Tech in 1966, and a Ph.D. in Electrical Engineering and Physics from Cal Tech in 1970.

From 1969 to 1971, he was a research fellow at Cal Tech; and from 1971 to 1973, he was a visiting scientist at the University of Regensburg, West Germany. From 1973 to 1978, he was a research staff member and manager of exploratory bubble device research at the IBM T.J. Watson Research Center. In 1978, he joined Carnegie-Mellon University, where he is now Professor of Electrical and Computer Engineering and Director of the Engineering Research Center in Data Storage Systems, which he founded.

Professor Kryder has over 150 papers and 10 patents in the field of magnetic materials and devices. Currently, he is actively involved in research on magnetic and magneto-optical recording technology. Mark, it's all yours.

DR. KRYDER: Thank you very much. I hope we are going to have some fun this afternoon. The success of this panel in this afternoon's activity really depends on the audience. You know, the speakers are going to get up here and make a few statements; but it really depends upon you, the audience, to challenge them and to provoke some controversy and get some good discussions going.

So, I hope you are all primed and thinking about getting some of those controversial questions out there.

What we are going to try to do is to have a panel discussion on the archival characteristics of various tape media. And we have representatives here from a large number of organizations; and we will actually have an opportunity to hear from people talking about chromium dioxide, cobalt gamma type materials, as well as metal particle and metal evaporated type materials, as well as barium ferrite.

And we will hope to see some comparisons of those; I hope to maybe find out what some of the problems are. We may not come to any solutions here, but the hope is that we can identify some of the problems; and maybe we can conclude that some of the problems that people thought were there really aren't problems.

Anyway, we would like to get the issues out on the table.

What we are going to do is this: We have a number of people to bring up here, and I have asked each group to go no longer than 15 minutes--absolute maximum--in their presentation. There are really five groups; so, that means we will have an hour and 15 minutes of presentations maximum.

And then, following that, we will have an open panel discussion.

Now, in order to make room for the viewgraphs and so forth, although later on we will ask all the panel members to come up when we have the discussion session, I have decided to have them here in the first row at the beginning; and then, we will let each one give the individual presentation and then take their seat. And then, when it is time for the discussion, everybody will come forward.

What I have tried to do is organize the session from the historical perspective forward in terms of when various media were introduced.

So, the first person this afternoon whom I am going to have speak is Dr. Barbara Reagor from Bellcore. She is Division Manager of Chemistry and Materials Science Research. She has 21 years experience in contamination and materials reliability in telecommunications and data center environments.

From 1970 to 1983, she was at Bell Laboratories. From 1984 to date, she has been with Bellcore. She has a B.S. in Chemistry from Monmouth College in New Jersey, an M.S. in Organic Catalysis and a Ph.D. in Chemistry, doing work on pico-second laser spectroscopy, from Seton Hall University in New Jersey.

Barbara will talk about the environmental impacts on mass storage systems, with particular emphasis on chromium dioxide in the 3480 cartridge. Barbara?

ENVIRONMENTAL IMPACTS ON MASS STORAGE SYSTEMS

Dr. Barbara Reagor
Bellcore

DR. REAGOR: To give you an overview, back in 1986, what brought my Bellcore group into involvement with this was the appearance of an article of this nature saying that chromium dioxide tapes would pose a toxic hazard for employees as well as environmental disposal of the units.

(Showing of viewgraphs)

DR. REAGOR: The companies that own Bellcore are all of the regional Bell operating companies; and our use of data is quite extensive in data storage.

We basically must store for greater than ten years all of the telephone call transactions that go through this country, all of the billing information, all of the operational parameters of the switching equipment. And we were very concerned about the reliability of tapes, in particular if there are questions being raised about their environmental robustness or in terms of their toxic characteristics.

The types of long-term stability we are looking for are the impacts from indoor air pollutants, heat and humidity, and also again this question of toxic removal.

We have heard a lot today about different tapes. (Change of viewgraph)

DR. REAGOR: And I threw one of these in very quickly just to give an overview of what the magnetic metal oxide tapes were like, where we have your metal oxide particles--iron oxide or chromium dioxide--embedded in a polymer-based binder. That binder can be an elastomer of polyurethane; it may have lubricants, dispersants or curing agents, as well as other additives in it to give it its various properties.

And then, we have our polymer base, which is usually PET, polyethylene terephthalate; PVC, polyester, or cellulose acetate material.

MAGNETIC TAPES -

- Information storage (10+ years)
  telephone calls, billing records, etc...

- Long term stability
  - pollutants, heat, humidity,...

- Disposal
  - no toxic components

In doing our study, we approached this from the sense of trying to learn as much as we could about the new chromium tapes. In 1987, we purchased seven different vendor products, all chromium tapes, all 3480 IBM compatible materials.

And these are the tests we subjected them to: differential scanning calorimetry to see how it responds to heat cycling and heat tests; thermal/mechanical analysis, where we look at the stretching parameters as we heat and move this tape in use; thermogravimetric analysis.

And we actually developed a magneto- thermogravimetric analysis technique, where we could look at the effect of heating in the presence of a 150 Gauss magnetic field. We did the magneto-hysteresis to see the impact of aging and chemical stressing on these tapes; and other typical chemical analyses, with FTIR analysis, extractions, X-ray spectroscopy, as well as macroscopic investigations.

(Change of viewgraph)

DR. REAGOR: In terms of some of the thermomechanical studies, what we would look at is a glassy type material at room temperature. You could slowly extend the materials, strain them as you start to heat. You would then see stress relaxation of the coatings on the physical binders.

And finally, if we got to about 200° C, we would start to see melting of the actual binder and substrate materials. And we looked at the effects this had on the magnetism.

(Change of viewgraph)

DR. REAGOR: If we ran a TGA analysis, we would start to see some very interesting things. With the TGA, we can find the Curie temperature, where we lose all magnetism. That is where the chromium tapes do have a disadvantage over iron.

In a chromium tape, as you scan the temperature range, when you reach about 120°C, you actually lose magnetism--at the Curie point, about 125°C for these tapes. We could actually monitor this with and without magnetic fields.

We would watch the deterioration of the actual substrate; comparing that to the case of an iron oxide tape, where the Curie temperature is 600°C, you have no loss of magnetism with that type of system.

(Change of viewgraph)

DR. REAGOR: To correlate it a little bit better. We could even do some interesting things where we could identify the actual degradation of the materials using these types of techniques.

We can see the effect of alignment of the chromium particles at the Curie temperature; we actually start to see a disalignment of the particles, a loss of magnetism, as they become mobile within the matrix of the binder.

As you reach the Curie point, we can look at the actual degradation. And a lot of work was put into using this material to actually analyze the tapes.

One of the things that we were able to learn from this--and it can be shown here --

(Change of viewgraph)

DR. REAGOR: Is we would look on when the alignment onset changed--at what temperature. At what temperature do we actually see the particles on the tape start to move and to lose alignment from a magnetic field? And in all of the tapes, the binder onset for alignment were showing up in about the 83° C range. We were able to obtain, like I said, through this method the Curie temperatures; and it shows you right here that T- 5 was actually an iron oxide tape and not a chromium dioxide tape.

From these types of information, from the weight gain and the loss of weight, depending on whether we have magnetic fields in place, we could determine the actual percent of substrate, the percent of metal, in the systems. We could take these all the way to total combustion; and in doing that, what we actually came up with was almost all of the tapes really were between the 30 and 35 mm thick PET films; and they had between 2 and 4 mm of coating in terms of the metal oxide. Yesterday, you heard a lot about the coercive force, about applied fields.

(Change of viewgraph)

DR. REAGOR: I put this up just as a way of explaining some of the data I'm going to talk to you about. When we do magnetohysteresis measurements, what we gain out of this hysteresis loop is that we can then get our remanent magnetization measurement. We can see our saturation magnetization; we can develop and measure the tape, and the surface roughness drastically changes the frictional drive.

PARTICIPANT: How long was the aging?

DR. REAGOR: 15 to 30 days. 85 degrees. This is not unreasonable for being in the back seat of your car on a humid day, and transportation was an issue. It is not unreasonable if you are in an environment that is in a disaster situation; and we have to maintain the possibility of that.

We also did, just looking at a variety of tapes, and we did studies of this nature, where we kept the temperature low and high.

(Change of viewgraph)

DR. REAGOR: We changed the humidity; we actually measured this magnetic weight. It gives you a feeling for how much magnetism is still retained in the tape and looked at the percent losses that we would see.

And again, situations that developed--massive changes--are shown here. At low temperature, basically just a little bit above room temperature, the humidity alone and the low temperature alone don't really hurt us unless it is an acidic medium.

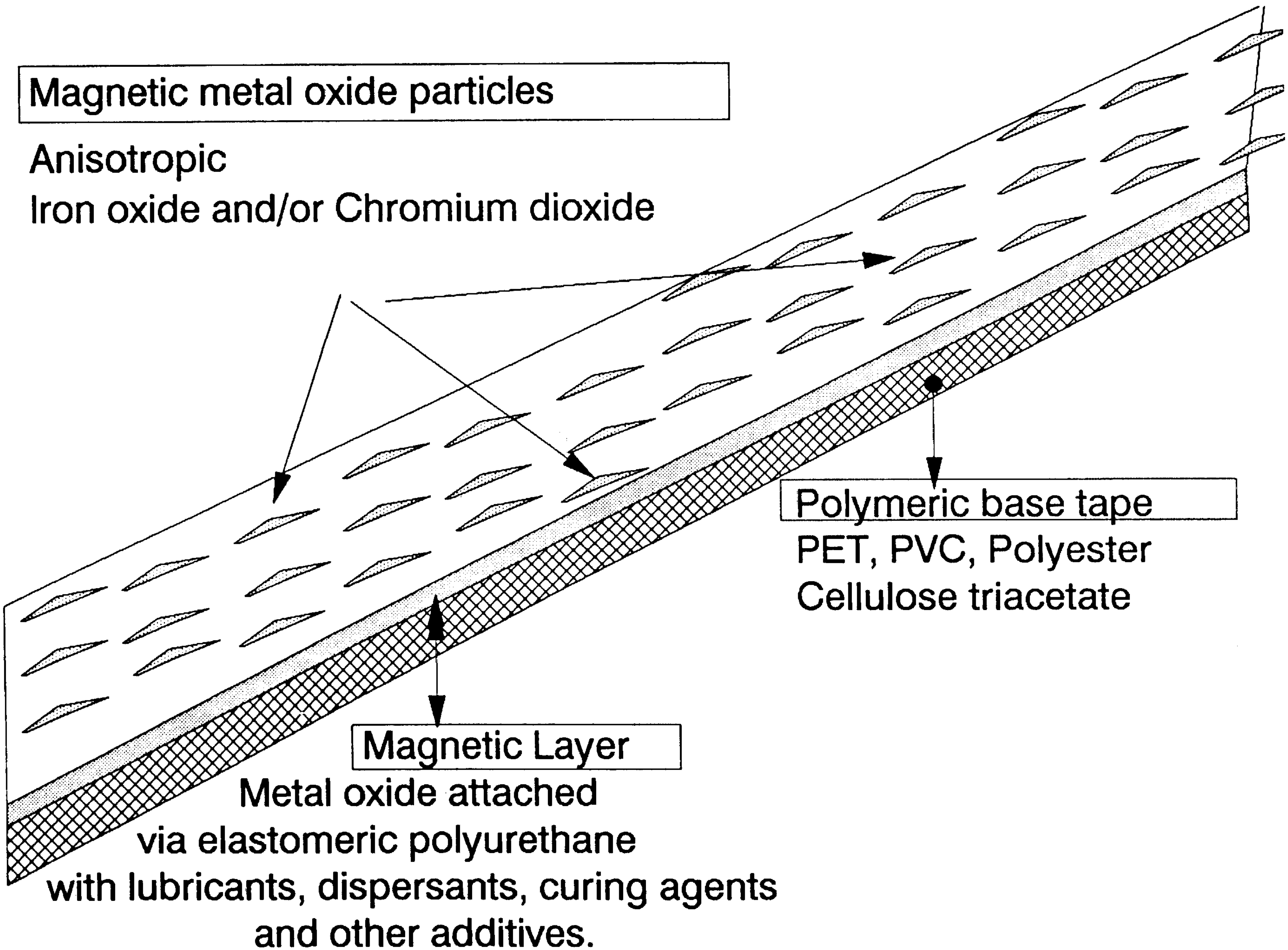
If we have acidic conditions at 30°, yes, we will see 20% loss of magnetic ability. If we are on the other side, if we are in high pH conditions --basic conditions--we actually only see 5 percent for the same situation.

Once we go into the 85° areas, we are starting to see losses in all of these tapes for the conditions. These are short-term exposures--two hours--for the tapes.

If we look at, again, three different tapes--this is the iron tape--again T-5; and that one behaved very, very well no matter what pH. It was actually the best performer of the group, which still says something for the iron oxides.

(Change of viewgraph)

DR. REAGOR: To give you a feeling for the analysis of this and just what we did in terms of looking at the tapes, in doing the elemental analysis of the materials, we found all of the chromium tapes still contain iron. That may be a trade secret; I'm not sure. But basically, there are still iron magnetic materials in all of these tapes except, like I said, for the T-5 which did not have any chromium.


Magnetic metal oxide particles
Anisotropic
Iron oxide and/or Chromium dioxide
Polymeric base tape
PET, PVC, Polyester
Cellulose triacetate
Magnetic Layer
Metal oxide attached
via elastomeric polyurethane
with lubricants, dispersants, curing agents
and other additives.

- DSC
- TMA
- TGA
- MAGNETO-HYSTERESIS

- FTIR / ATR
- EXTRACTIONS
- X-RAY, MICROSCOPY

THERMOMECHANICAL STUDIES

<u>Below room temp.</u>

flat TMA trace = glassy material

<u>30-85 deg C</u>

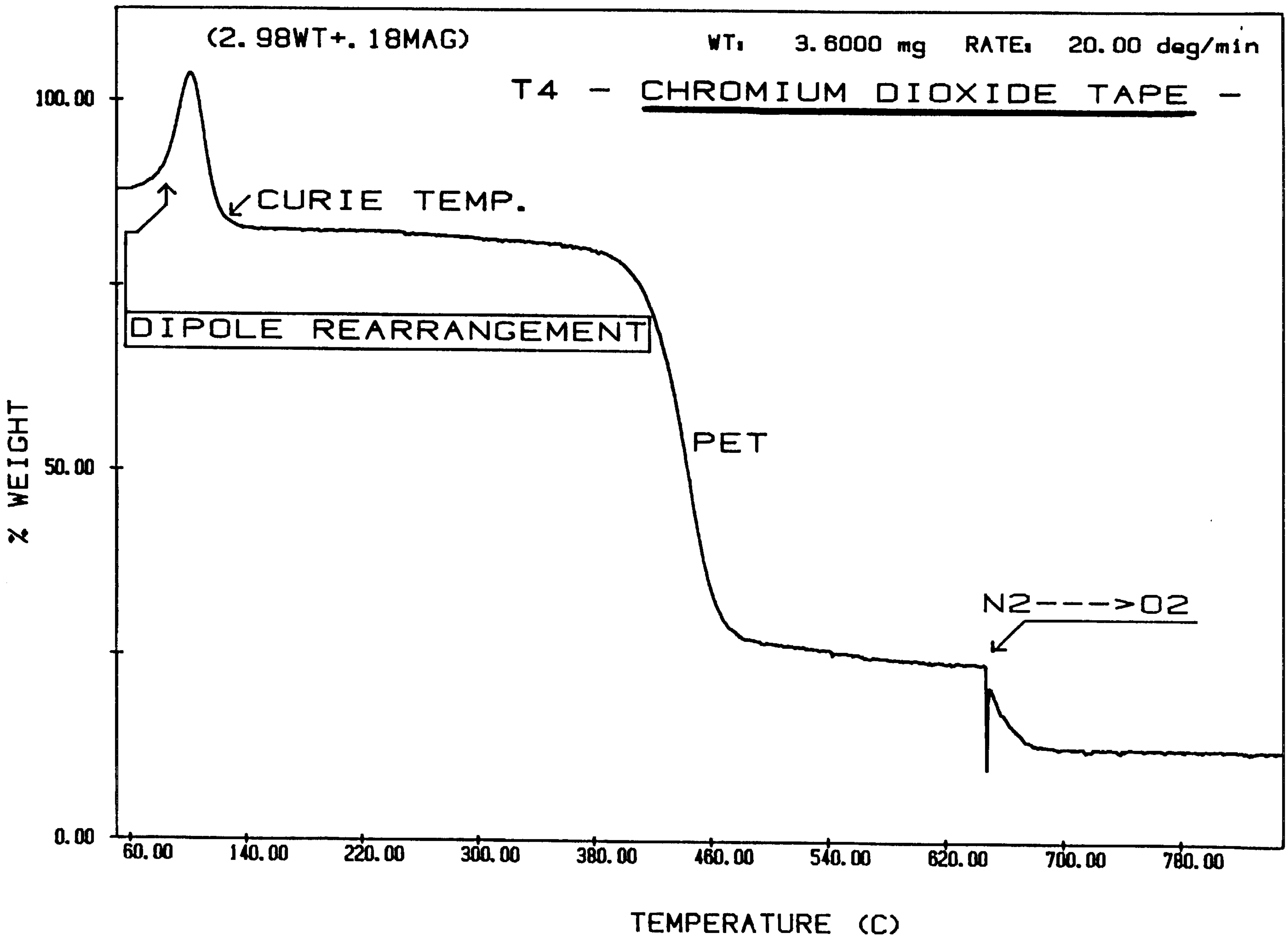
extends slowly reaching a max. strain of 0.002 at 70-80 deg C

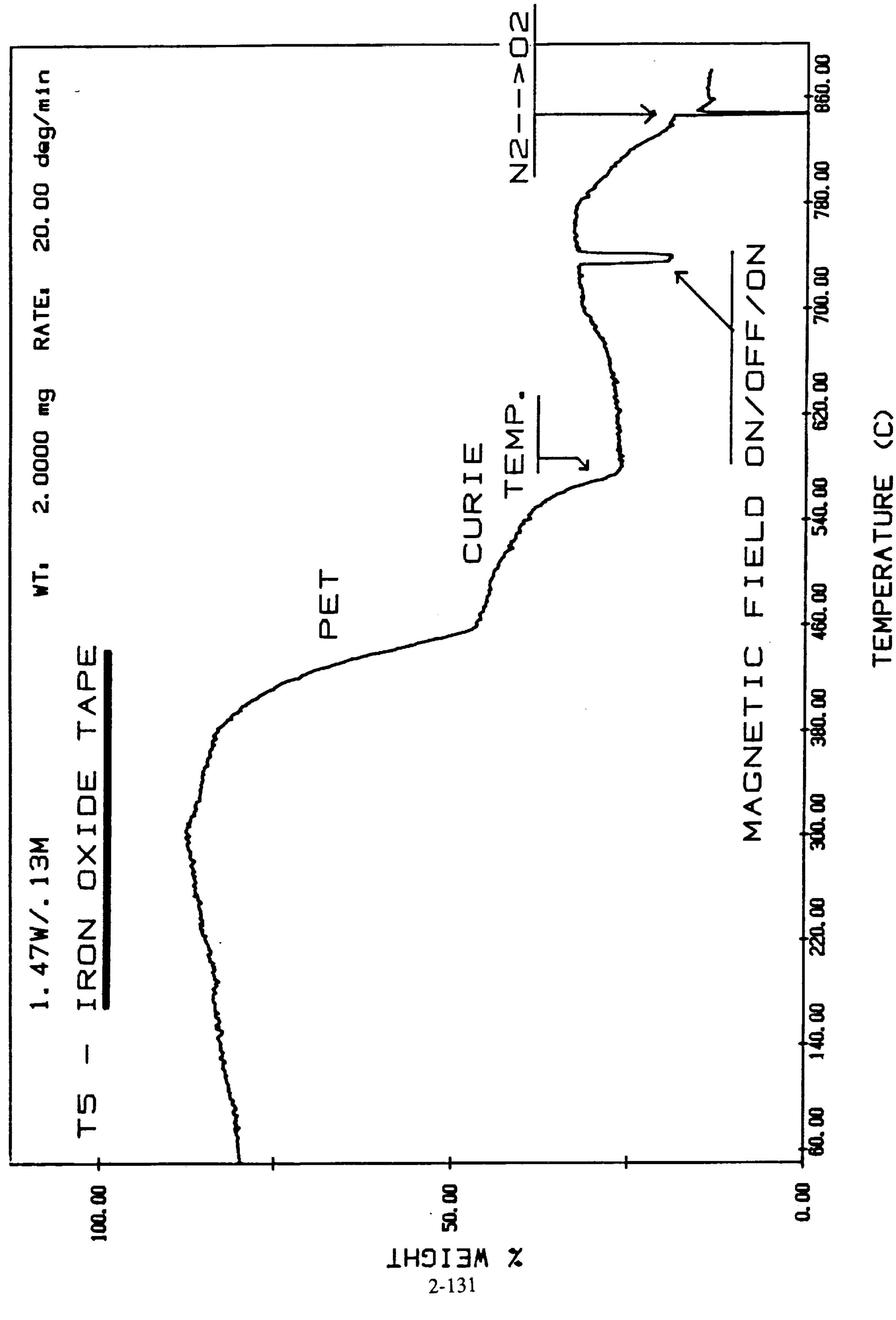
<u>85-200 deg C</u>

contractions begin at 80-90 deg due to stress relaxation. Above 140-150 deg C, it contracts at an increasing rate until 200 deg C

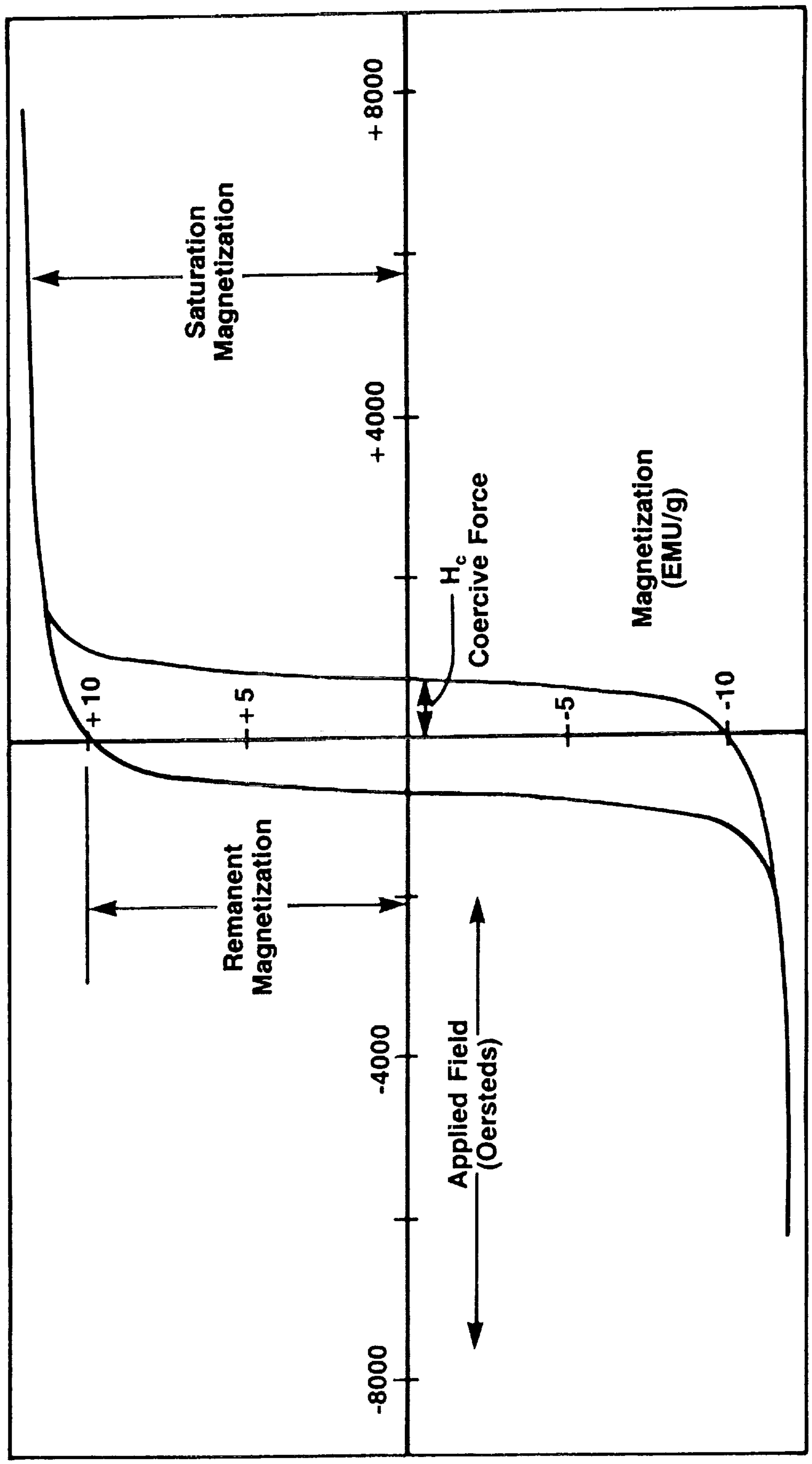
<u>Above 200 deg C</u>

Melting point approached, PET flows and extends, eventually breaking at 230-240 deg C


(2.98WT+.18MAG)
WT: 3.6000 mg RATE: 20.00 deg/min
T4 - CHROMIUM DIOXIDE TAPE -
CURIE TEMP.
DIPOLE REARRANGEMENT
PET
N2--->O2
100.00
50.00
0.00
% WEIGHT
60.00
140.00
220.00
300.00
380.00
460.00
540.00
620.00
700.00
780.00
TEMPERATURE (C)



1.47W/.13M
WT: 2.0000 mg
RATE: 20.00 deg/min
TS - IRON OXIDE TAPE
PET
CURIE TEMP.
N2--->O2
MAGNETIC FIELD ON/OFF/ON
TEMPERATURE (C)
% WEIGHT
100.00
50.00
0.00
60.00
140.00
220.00
300.00
380.00
460.00
540.00
620.00
700.00
780.00
860.00


Saturation Magnetization
Remanent Magnetization
H_c Coercive Force
Magnetization (EMU/g)
Applied Field (Oersteds)
+8000
+4000
-4000
-8000
+10
+5
-5
-10

Frictional Drag Results

TAPE	Frictional Drag (pounds)	
	new	aged 85C/85%RH
IBT1	0.27	0.52
IBT2	0.34	0.55
IBT3	0.54	(a)
IBT4	0.61	0.49
IBT5	0.49	0.64
IBT6	0.38	0.38
IBT7	0.42	0.53

(a) insufficient aged material for testing.

W_m = weight increase due to magnetic field

= defined as magnetic weight

W_{mp} = magnetic weight at peak maximum during 100-120 deg C magnetic transition

---

W_{m3} = maximum magnetic weight obtained by cooling from 175-200 deg C in the presence of the magnetic field (150 Gauss).

Magneto-Hysteresis Results
(aged = 1 month in 85°C-85%RH)

TAPE	Coercive Force, H_c (Oersted)		Magnetization Remanent R		Magnetization Saturation S		Percent change
	new	aged	new	aged	new	aged	(a)
C1	570	520	11.1	5.99	13.6	7.68	-45%
C2	513	487	9.67	6.16	11.2	7.56	-35%
C3	537	515	12.6	7.56	14.8	9.05	-40%
C4	530	500	9.70	5.36	11.5	6.64	-43%
F5	687	681	10.1	9.91	11.9	11.80	- 2%
C6	539	500	11.0	6.23	12.9	7.72	-42%
C7	536	497	8.59	4.74	10.3	5.99	-44%

(a) percent change = average of changes in R and in S.

Magneto-TGA Analysis

Tape	W_m/M x 100	Magnetic Transition onset (°C)	Magnetic Transition W_{mp}/W_m	Curie Temp. (°C)	900°C Residue (% of M)	Composition PET %	Composition Coating %
C1	7.5	85	4	122-5	18	76	24
C2	8.0	83	3	120-7	16	77	23
C3	8.6	89	4	122-7	20	70	30
C4	6.7	83	4	122-9	14	80	20
F5	9.2	90	1.5-2	585	18	75	25
C6	7.0	92	4	122-6	18	70	30
C7	6.8	91	4	120-7	17	75	25
PET	0	-	-	-	0	100	0

30 - 35 μm PET
2 - 4 μm coating

W_{m3} Values after Aging in 85°C-85%RH Chamber

TAPE	W_{m3}/M new	W_{m3}/M aged	percent decrease
C1	0.50	0.25	50
C2	0.48	0.40	20
C3	0.59	0.3	50
C4	0.47	0.27	40
F5	0.12	0.13	0
C6	0.44	0.28	40
C7	0.37	0.19	50

We looked at the effect of iron-to-chromium ratio and its effect on being changed as we dulled the tapes. Dulling was caused when one put these through the environmental stressing situations.

And again, you can see the ratio of these peak areas was changing slightly as we go in terms of the shiny and the dull; the ratio is changing because we were basically corroding the metal, forcing it deeper into the surface. And with the technique we were using, we were trying to do a surface ratio penetrating very lightly into the surface of the tape structure. And this gave us a good feeling for the actual surface composition being changed by the actual study.

(Change of viewgraph)

DR. REAGOR: All of this work, putting together, basically brought us to a proposal for what the degradation mechanism was and that there were two mechanisms that could impact the tape. One was a chemical one, where we could have an acid catalyzed hydrolysis; it was the binder in all cases that was allowing the loss of magnetism as well as an interaction of the particle surface with the binder that could reduce some of the magnetism.

We were seeing in a physical sense that thermally induced disordering where the particles could misalign and we would lose their magnetic effect were showing some entropic relaxation.

What we saw in these cases was that these two types of degradation mechanisms would reduce the adhesion of the magnetic particles to the tape. And if you do that, then your alignment and your magnetic fields would have less effect for read/write. We would see it disrupt the particle array, and we would see orientation changes in the tape; and that was critical if we were in a longitudinal tape reading mode and all the CrO_2 particles are going off axis.

And the thing with the chromium that we liked so much was these elongated needles that gave us our best magnetic reading capability. And now, all of a sudden, I'm changing the configuration of that needle, and I'm not using its long length; I'm now using its width because it's turning away from the longitudinal axis, that we can see that that can disrupt our ability to read/write.

And then, we were seeing that we could actually create defect sites, that as you read across the tape, these disorders--the small amount of corrosion--could lead to problems.

This work was actually published in a paper, and I'll just give you the source. It was published in the book by Mittal called ***Polymers in Information Storage Technology.*** * The key team leader here was Trevor Bowmer, and he published it as "Characterization and Hydrolysis of Magnetic Tapes."

Our lawyers would not allow us to use the term "3480" anywhere in the publication because they thought that was a trade name and that would look as if we were doing a product analysis. So, there is this paper; it was published in 1989 based on a very large amount of work that was done on these tape materials.

Additionally, we did solvation studies and extraction studies; and we looked at the solvent impacts on all of these different tape materials. The one material that affected all of the tapes in terms of long-term exposure, we had five 15-minute exposures to different types of solvent systems and then greater than 24.

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* K. L. Mittal, ed: Polymers in Information Storage Technology (New York: Plenum Press, 1990)

Aging Results for C2,C3 and F5.

Tape	Conditions Temp.	%RH	pH	W_{m3}/M after 1 mth	percent loss
C2	30	20	-	0.48	0-5
	30	70	-	0.46	0-5
	30	100	4	0.38	20
	30	100	10	0.45	5
	85	< 5	-	0.42	15
	85	20	-	0.39	20
	85	85	-	0.40	20
C3	30	20	-	0.64	0-5
	30	70	-	0.63	0-5
	30	100	-	0.62	0-5
	30	100	4	0.44	33
	30	100	7	0.62	0-5
	30	100	10	0.64	0-5
	85	< 5	-	0.49	25
	85	20	-	0.38	40
	85	85	-	0.30	55
	100	< 5	-	0.35	45
F5	30 ↓ 100	< 5 ↓ 100	4 ↓ 10	0.13	0-5

X-ray Analysis.

TAPE	Cr/Fe Peak Area Ratios (a)				Elements found on shiny side
	new		aged 85C/85%RH		
	shiny	dull	shiny	dull	
IBT1	21.5	2.5	22.7	2.9	Fe,Cr,O,no C
IBT2	56.3	2.7	56.9	2.5	Fe,Cr,O,no C
IBT3	55.2	2.8	51.2	2.6	Fe,Cr,O,no C
IBT4	52.7	2.6	52.9	2.4	Fe,Cr,O,Cl,no C
IBT5	0	0	0	0	Fe,no Cr,O,Al,Si,no C
IBT6	54.8	2.7	51.8	2.5	no Fe,Cr,O,no C
IBT7	46.9	2.5	40.9	2.4	Fe,Cr,O,no C

DEGRADATION MECHANISM

CHEMICAL

Acid catalysed hydrolysis

PHYSICAL

Thermal-induced disordering

Entropic relaxation

(A) reduces adhesion of magnetic particles to tape

(B) disrupts particle array/orientation on tape

(C) creates defect sites - disrupting magnetic domains

We saw either no impact, or we saw a small amount of deterioration of the binder. The one product that did impact them all was halon-211, in a long-term exposure; five 15 minutes, no change; 24 hour soak time, a noticeable deterioration in the binder of the tapes.

I raise this right now because halon-211 is leaving us, and we are going to see some new halon products; and it is going to be vital that the studies of any tape medium be done with these new halon replacements to ensure that we don't have short-term exposure changes for those materials.

That was the basis for the talk I had provided for the conference; and one additional thing I wanted to bring up is a concept for you.

(Change of viewgraph)

DR. REAGOR: At this point in time, we use the chromium-based tape in all of our data centers. I have 75 maxicenters across this country with more than 10,000 DASDs in operation at this time; and those 10,000 3380 DASDs are dumping to the 3480 magnetic tape. And then, that goes into our storage.

The numbers, I can't tell you. I can't tell you the number of tapes, but it is an ungodly large number. And we are required by law to store this magnetic media minimally ten years. And it has everything you can imagine on it in terms of a telephone call placed in this country: date, time, to/from, what carrier it went through, and the whole bit.

And that is an awful lot of data that needs to be stored and retrieved; and so, from a user standpoint, we are very concerned.

The difference I see is that this is the concept of a typical data center, like our typical data center, like your typical data center. A controlled environment, filtered from a major system, and then uniquely filtered with high change rates inside.

We know that they are not highly contaminated areas yet.

(Change of viewgraph)

DR. REAGOR: Sometimes, this is typical of what they look like in terms of contamination.

The difference between a data center and a telephone switching office is basically in the particulate level and the temperature windows. From a particulate standpoint, this gives you a good feeling of what a low activity and a high activity data center--D.C.--versus a telephone center office, in terms of low activity.

Our data centers in those spaces stay under the 10,000 particle per cubic foot at .5 micron; so, basically, a 10,000 foot clean room.

High activity in a normal central office is still below the 100,000 that we set for computer standards. I bring this up since we are now moving the processing and storage capability of the computer center, and it is being merged with the electronic switch. And this is happening on a daily basis.

When you pick up your phone today and want to look at caller I.D. or have the various calling features, that is being done on the switching product with the 3480 line, some products with a 340 megabyte drive system, on- line storage of data right there in the switching office.

The difference that we see for the future is that that move to have storage within the central office is going to be greater, but we are going to have a higher need for data storage and data manipulation within the management of the system.

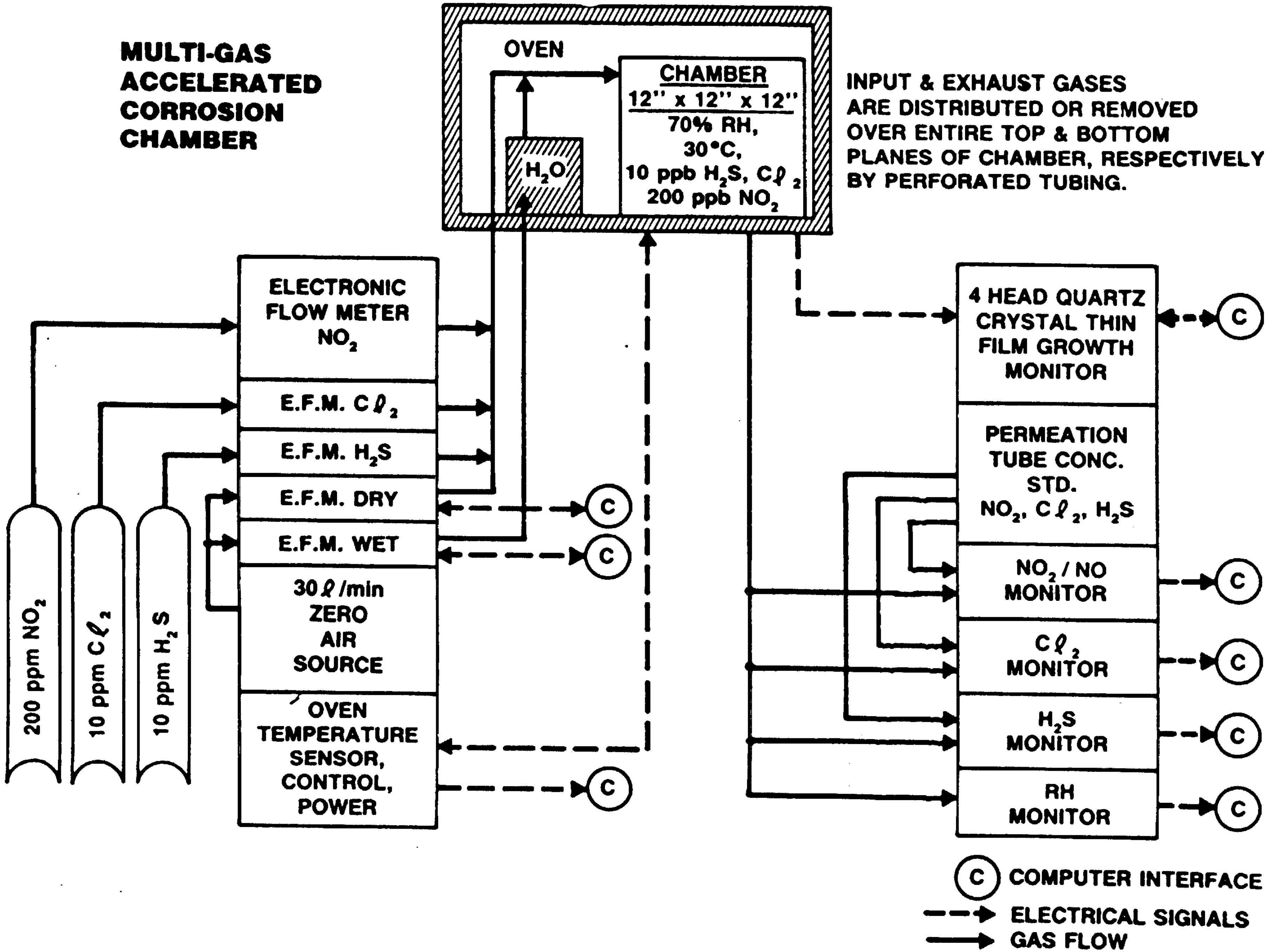
Corrosion Chamber

(17days > 10 years in the field)

- 30 deg C
- 70% relative Humidity (RH)
- hydrogen sulfide - 10 ppb
- chlorine - 10 ppb
- nitrous oxide - 200 ppb

in an air stream

MULTI-GAS ACCELERATED CORROSION CHAMBER



We are going to have user influenced telephone systems, that as a user I can, with the touch of a dial, change what I get for information or change where I go in terms of pathways that I can select one carrier one day and another carrier another day. To do that, you now have to maintain a computer system in this environment because these are the standards for telephones.

The operating environment is from 40°F to 100, a minimum of 35 and a maximum of 120. The nominal temperature will swing 12 degrees an hour on any given day and will cycle in that range.

There is a humidity operating range of from 20 to 55% humidity; and it will float and is allowed to go as low as 10 and as high as 80, and the projections are now to go as high as 90. And in that environment, computing equipment and storage media must work. And so, we are looking at some interesting changes.

(Change of viewgraph)

DR. REAGOR: In addition, I have brought the environmental standards for gases and for contaminants. In both our data centers and our central offices, we only control particulates. The rest of it--whatever is outside --comes inside.

From the standpoint of robustness, we look at three ingredients that we recommend vendors must be able to withstand: 25 micrograms of dust per cubic meter of air; volatile organic compounds on the order of 1,200 parts per million; and ammonia to the level of 500 parts per billion. Ammonia is generated by people, and it's in the products we use to clean our floors; and it will always be there. The rest of these gases are typical 95% level, short-term exposure possibilities.

And all of these gases that are outside a data center or central office will be pulled inside that data center and central office, and their resident lifetimes are a whole lot higher than people realize.

I was very happy to hear the comment on ozone because we have measured the ozone; and depending on the outside air strategy of a building, you can have 80 percent of the outside level indoors as a constant level during the day. And that is a critical amount if your outdoor level happens to be 200 parts per billion.

And ozone is something that we actually have in our standard test now. And for our purposes, we have ozone levels as even potentially having a maximum of 500, which is everything outside plus the fact that I have laser printers and a variety of other products inside contributing to that type of level.

So, my words to you at this point are: We see chromium as a little bit less sensitive or less robust than the iron, but it is still good in our environment; but it is more of a word of wisdom to you that, for the future, we are going to need some very robust materials because we are going to be living in two environments.

(Applause)

DR. KRYDER: Write down your questions and make a note of them to yourselves because we are going to proceed all the way through the presentations before we entertain questions.

The next speaker will be Darlene Carlson. Darlene is a chemist working as Manager of Operations Support in the 3M National Media Laboratory. She has worked in magnetic media for 18 years with broad-based experience in media formulation and applications development.

Darlene was the principal investigator in the development and introduction of 3M metal audio tape in 1978. In recent years, Darlene has developed high-density digital recording tape for Government applications.

Darlene will be talking about the stability of cobalt-doped gammaferric oxide tape.

STABILITY OF COBALT-DOPED GAMMAFERRIC OXIDE

Darlene Carlson
3M National Media Laboratory

MS. CARLSON: Good afternoon. I would like to talk to you today about cobalt-doped gammaferric oxide; and you have heard a lot about a lot of different products out on the market today.

(Showing of viewgraphs)

MS. CARLSON: The question is: Why are we so interested in cobalt-doped gammaferric oxide?

If you consider the entire recording industry, cobalt-doped gammaferric oxide is basically an order of magnitude more in production than any other medium that is in the market place. It is a work horse; it is the cost driver. It is what makes the media manufacturers, both here and in Japan, churn. This is the driving force.

So, you really have to understand why people are involved in cobalt-doped materials.

The question is always: What is the stability of the materials?

(Change of viewgraph)

MS. CARLSON: What I've done is given you an overview of the various types of recording media. And what we are talking about is basically a consumer's report type thing, looking at temperature, humidity, the pollutants in the Class II Battelle environment, and then a combination of those two.

And what you can see is that the normal iron oxide, which is your typical instrumentation tape, is better than the cobalt-doped iron oxide. Now, I'll get into the reason why that is; but it is also better than the MP and the metal evaporated and the cobalt chromium that is coming down the line.

(Change of viewgraph)

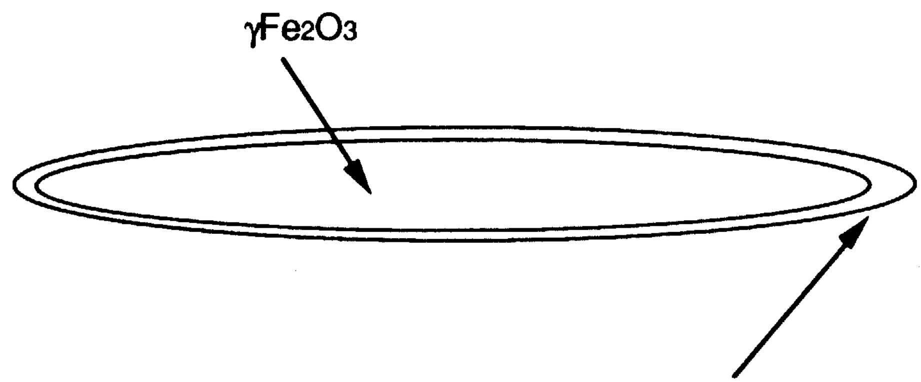
MS. CARLSON: What I'm talking about here is the surface-modified or surface-adsorbed cobalt material; and what we have is an interior material of g-ferric oxide in there, which is the normal 300 Oersted instrumentation tape, that has been surface-modified with cobalt, which gives you a very interesting engineering material.

And if you remember John Mallinson, who was talking about the paranoia that people have in the recording industry because they are concerned about the next generation of thing that will overcome the recording media, my contention is that the reason why we are still with magnetic recording media is the versatility of this particular species.

We have a coercivity range of 450 to 900 Oersteds; and we have some control over the aspect ratio and the surface area. So, this is a very interesting engineering material, which has allowed us to 'fend off' all the different media recording technologies that are out there.

Co-γ-Fe_2O_3 Pigment

National Media Laboratory



Surface Adsorbed Co
Hc (oe)- 450-900
σs (emu/gm)- 84
l/d- 5:1 to 10:1

NML DMC 7/24/91

Storage Systems Using Co-γ-Fe_2O_3 Tape

National Media Laboratory

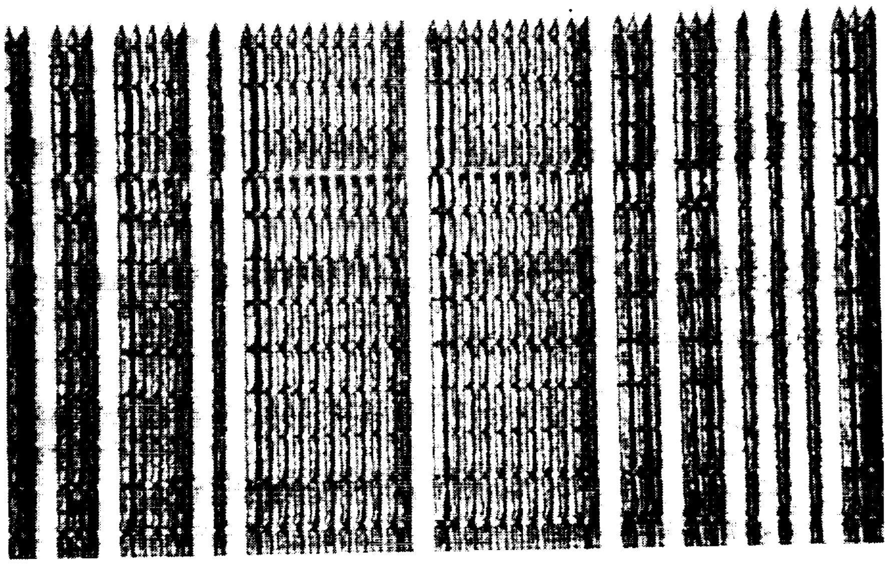
System ID	Head	Media Format	Thickness (μ)	Capacity/Pkg (Gbits)	Durability (passes)
QIC 525	Fixed	1/4" Cart.	11	4.2	10,000
QIC 1350	Fixed	1/4" Cart.	13	10.8	10,000
Interferometrics	Fixed	1"x14" reel	16	5500	1,000
DCRsi	Trans.	1" Cart.	25	380	200
VHS	Helical	1/2" Cart.	20	32	NI
Digidata	Helical	1/2" Cart.	20	43	NI
VLDS	Helical	1/2" Cart.	16	80	NI
ID1	Helical	19mm Cart.	16	300	300
DCR	Helical	1" Cart.	25	240	200

* NI - No Information

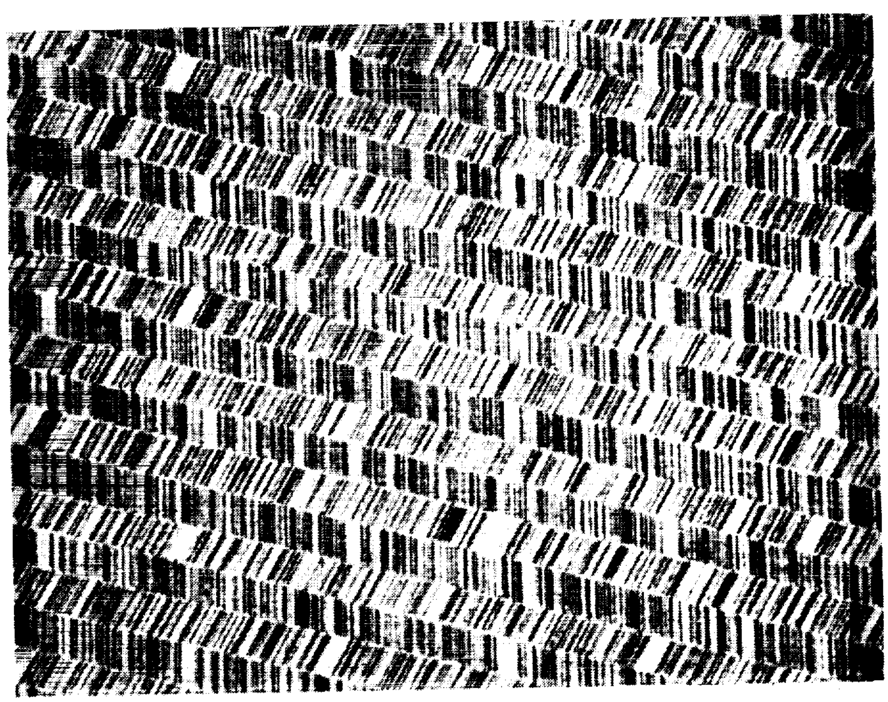
NML DMC 7/24/91

Recording Bit Density Comparison

Linear, Low Density: 2060 bits per inch, 20 mil width; 165X.



Helical, High Density: 45,000 bits per inch, 1.2 mil width; 165X.



(Change of viewgraph)

MS. CARLSON: It is used in a wide variety of systems, both in fixed transverse and helical scan material and a lot of different media formats. And it is coated on a lot of different thicknesses of materials.

And you can see that it has a wide range of capacity for package; and again, this is in gigabits, not gigabytes. And, depending upon the application, the durability has a wide range.

Now, one question is: How long can you archive this material?

(Change of viewgraph)

MS. CARLSON: Unfortunately, this particular viewgraph isn't very clear; but what I would like to do is do a bit of a comparison. This is a 2K bit; this is just one bit right here. And this is a -- technique of a search track on a digital recording system.

These bits are 20 mils wide, and these represent probably about three times as large as your 6250 bpi material that everybody is used to. But you can see that this particular -- shows you a 45K bits. So, when you ask: what is the archivability of cobalt-doped material?, it really depends upon your bit density; and the implementations and archivability of a 2K material or 6250 material is going to be much, much different than a 45 Kfci or as an 8 millimeter, we are going up to 75 Kfci.

So, you can see that these bits are actually getting smaller as you evolve into different products.

(Change of viewgraph)

MS. CARLSON: Similar to what Barbara was talking about, magnetic tape components have a lot of different contributions that could impact archivability. We have a coating layer of polyester, and some people have backcoating

And each of these components can be the weakest link in any archive system. Now, what I would like to do is take a broad-brush approach on what can happen to the various individual components in a tape system.

(Change of viewgraph)

MS. CARLSON: If you look at the substrate, what you are interested in is the dimensional stability and how that affects crossplay.

If you look at any ANSI standard or SMPTE standard or MIL standard, what we normally do is define the tape format on the tape. That's the system in which the head lays down your track of information.

Because of either tape shrinkage or tape creep, which is involved with tension on the tape, you can actually have the polyester changing so that your recorded track is outside of that tape standard. And therefore, you will not get crossplay; and sometimes, it can be so bad that you can actually lose self play.

So, dimensional stability is well known, and it is a concern in any archive environment.

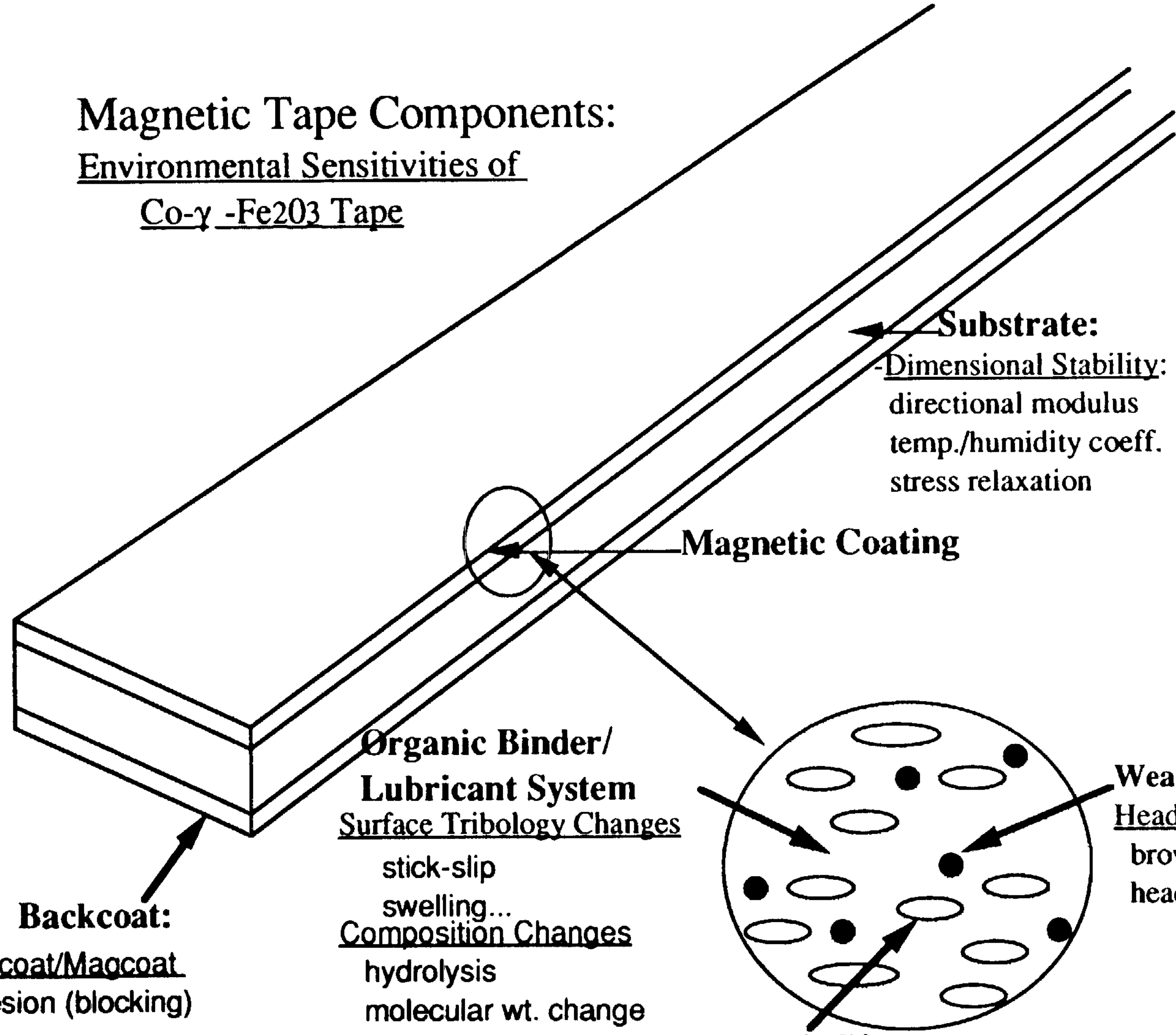
(Change of viewgraph)

National Media Laboratory

Magnetic Tape Components:

Environmental Sensitivities of

Co-γ -Fe203 Tape



NML DMC 7/24/91

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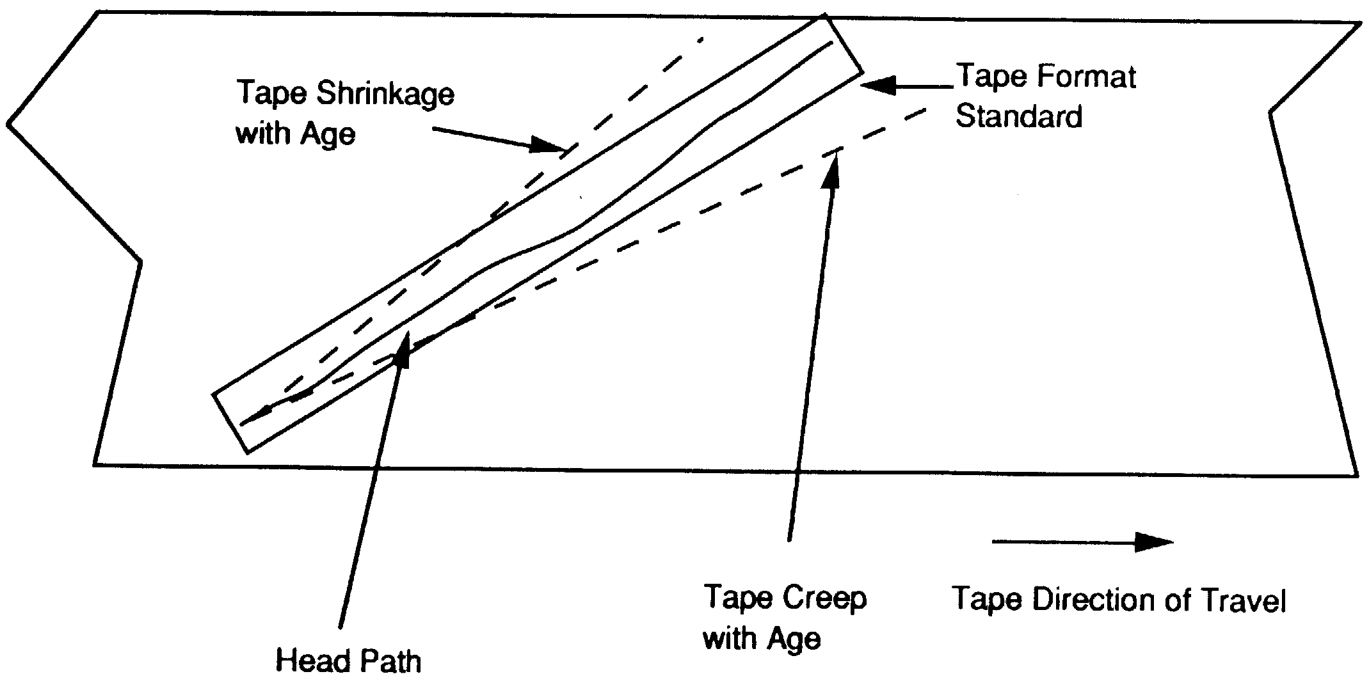
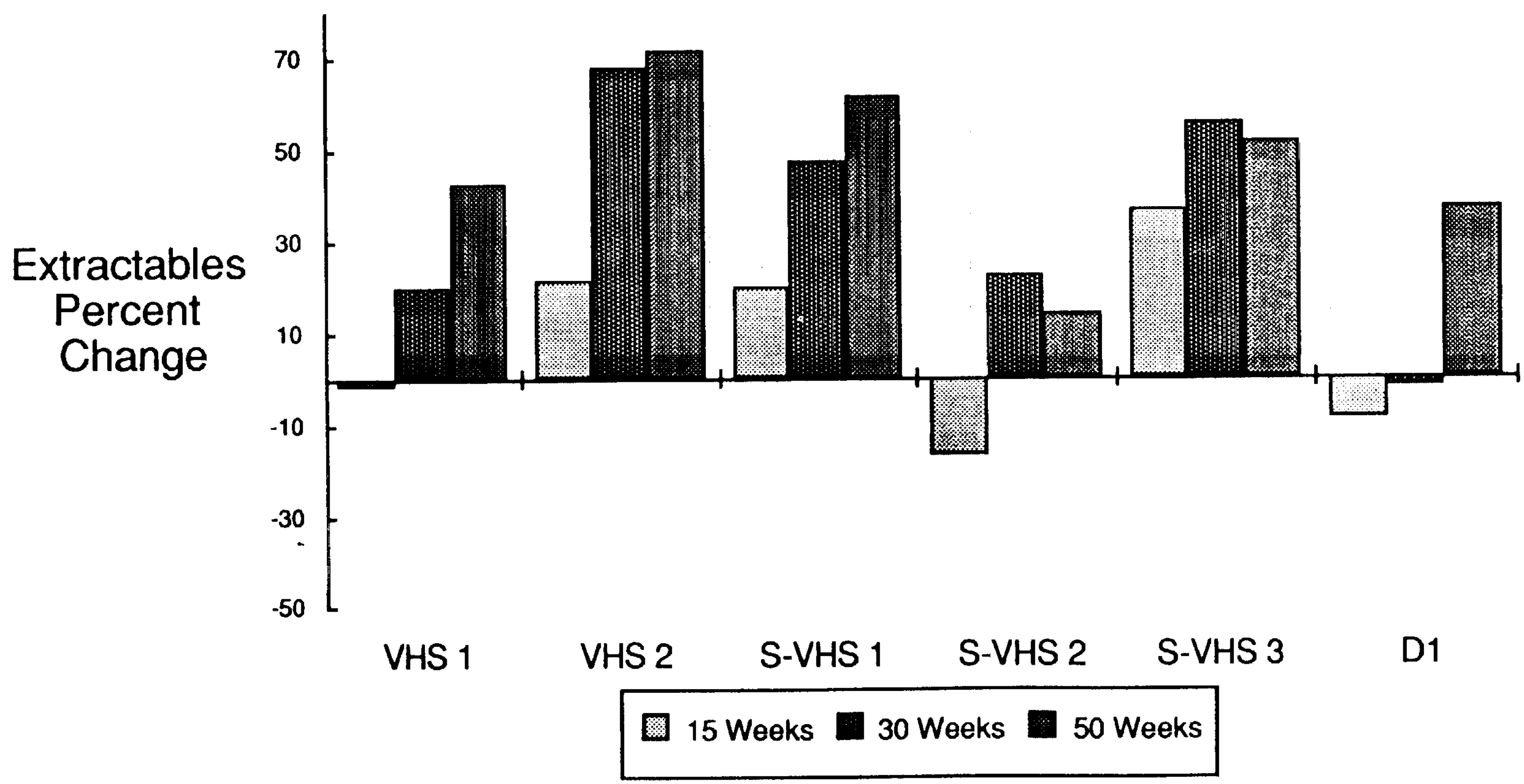
Dimensional Stability and Crossplay



NML DMC 7/24/91

National Media Laboratory

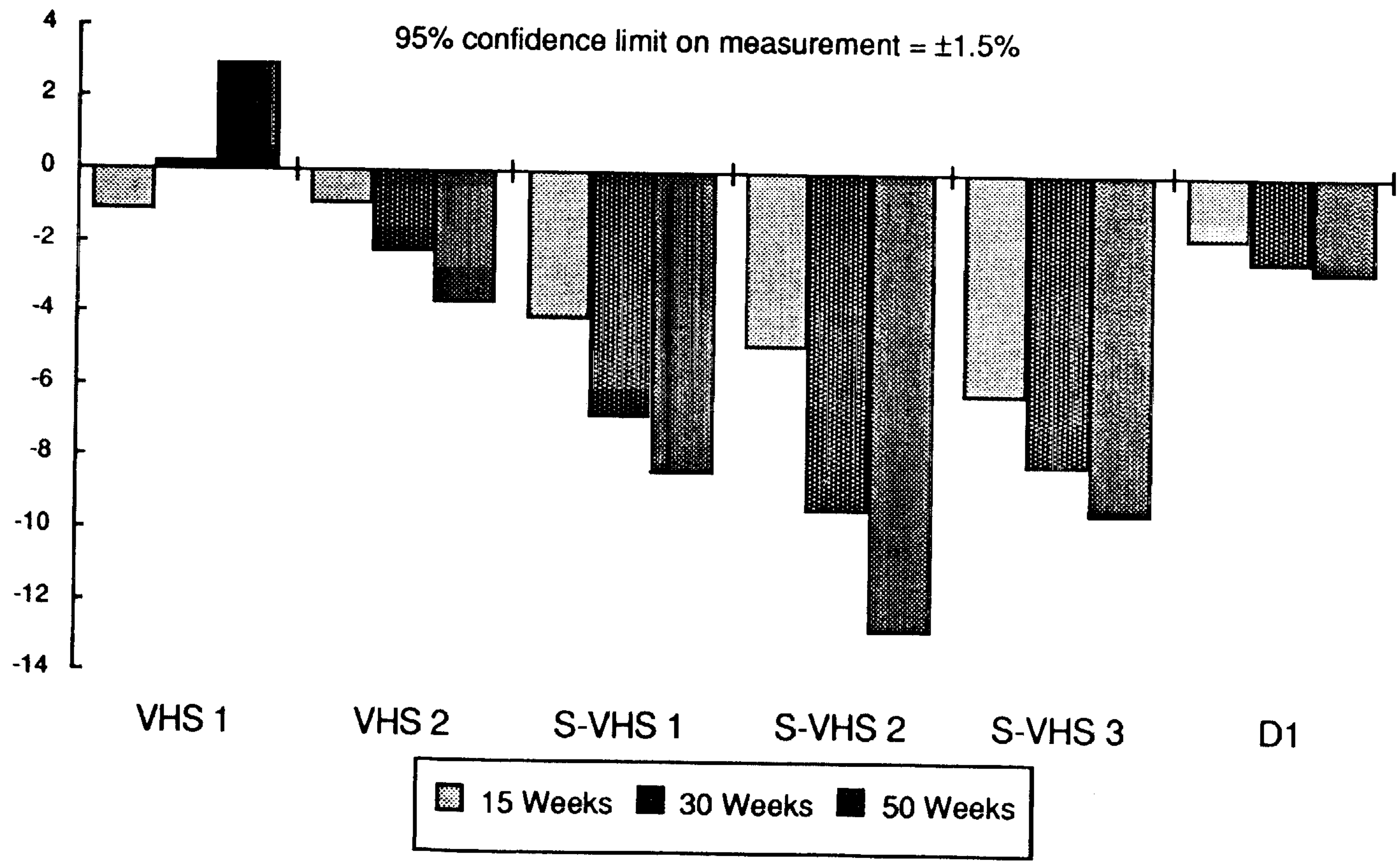
58°C - 90% RH
Acetone Extraction



NML DMC 7/24/91

National Media Laboratory

58°C - 90% RH
Coercivity



NML DMC 7/24/91

MS. CARLSON: Another thing that is of importance is the hydrolysis. Barbara talked earlier about hydrolysis of the binder and compared instrumentation tape with various tapes; and this is Co-doped material; and what you can see is that hydrolysis is still with us--it is alive and well.

And this is a solvent extraction at 58° C/90% RH; and we are looking at two different vendors of VHS tapes, three different vendors of S-VHS and D-1.

And you can see that, after 50 weeks--which is an extremely long period of time--that we still have hydrolysis. Now, the purpose of this study is that we have a family of curves that we are developing, and we are developing various equations from them; and we will have models to predict for all the various materials.

But you can see that in the cobalt-doped materials, we do have hydrolysis; and we will have to manage for that change.

(Change of viewgraph)

MS. CARLSON: If you remember the earlier slide, I told you that the cobalt-doped material is not as stable as other things like g-ferric oxide. And the reason for that is because of the coercivity change.

What happens is that the cobalt actually diffuses into the g- Fe_2O_3; and what you do is you lose coercivity. And again, what we are plotting here is the coercivity change at 58° C/90% RH at up to 50 weeks.

And you can see that there is a variation from different types of cobalt to how fast or what the mechanism of the cobalt migrating into the g-Fe_2O_3 is.

(Change of viewgraph)

MS. CARLSON: Now, in contrast, the f_R, which is the measure of the remanent magnetization, is very, very stable; and I don't know if you remember this from Barbara's talk, but chromium is much worse than this. And this is basically within the measurement error.

(Change of viewgraph)

MS. CARLSON: In summary, we have to be careful about how we specify any archive requirements. You can archive cobalt-doped gamma materials for up to ten years. Now, the caution that I have is that you have to retension and clean the tape.

In most mass storage situations recertification is not an issue because what you are doing is you are recording on one tape or reading from another or whatever. But if you are reusing a tape, it should be recertified.

The archive requirements are system-specific, specifically because there is such a wide range of requirements out there; and each system has its own peculiar way of being implemented.

And many times, a tape vendor recommends a certain range of temperature and humidity controls; but the user environment, as Barbara was saying, is outside of that. We recommend never putting a tape outside of a 70% RH environment.

And as we heard today, they realize that we will store at 95% RH. So, the question is: what implementation procedures should we utilize if we are storing at 95% RH? And that is what we are in the process of developing.

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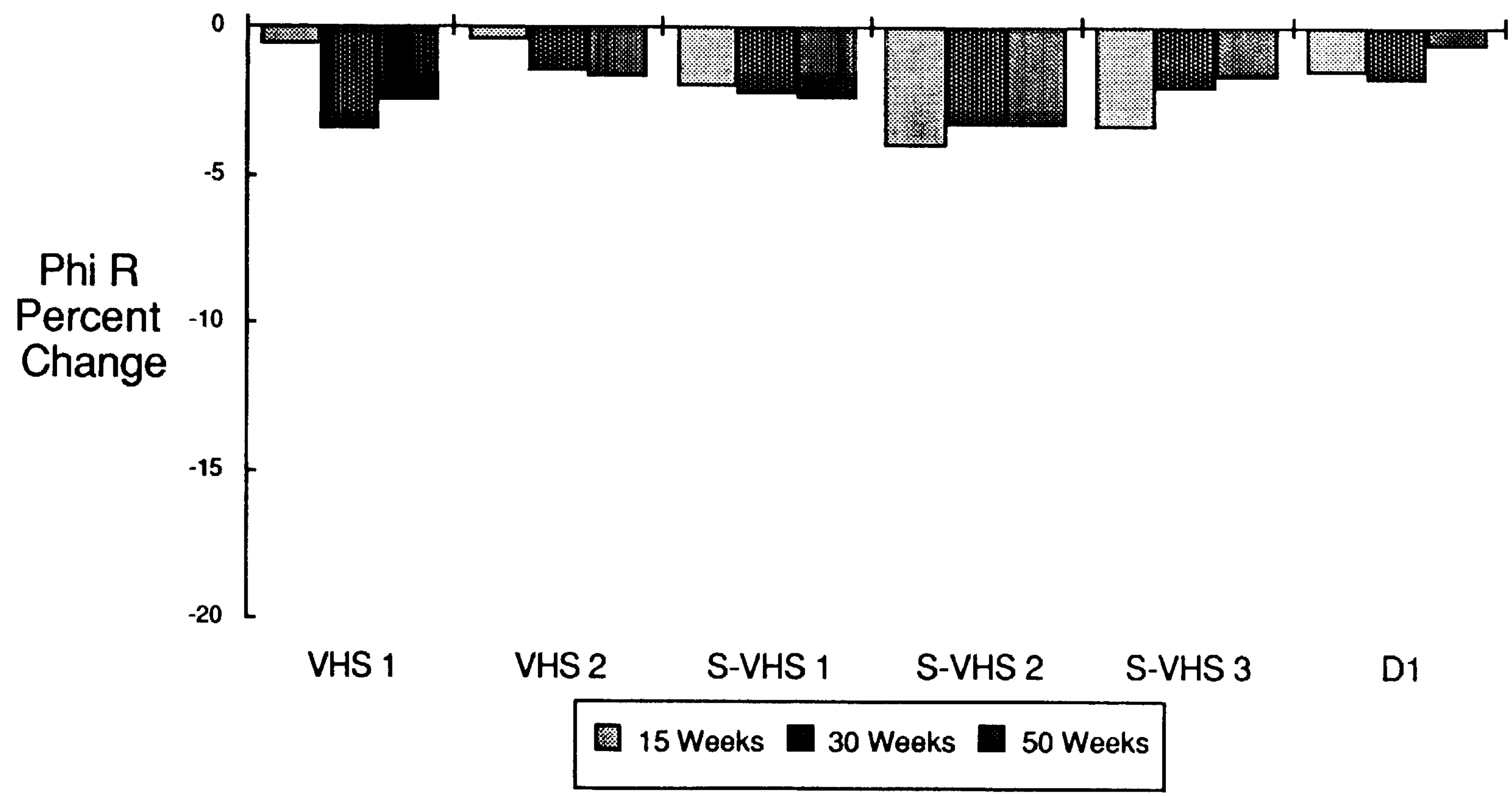
58°C - 90% RH
Phi R

95% confidence limit on measurement = ±6%



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Overview of Archival Stability of Recording Media

	Magnetic Pigment						
Environment	γFe_2O_3	CO-γ-Fe_2O_3	BaFe	CrO_2	MP	CoNi	CoCr
Temp ≥ 50°C	GOOD	GOOD	GOOD	FAIR	GOOD / FAIR	GOOD	GOOD
Humidity ≥ 75%	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
Pollutants ≥ Cl II*	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	GOOD
Temp & Humid	GOOD	FAIR	GOOD	POOR	POOR / GOOD	POOR	GOOD
Temp & Poll	GOOD	GOOD	GOOD	FAIR	FAIR	POOR	FAIR
Humid & Poll	GOOD	FAIR	GOOD	GOOD	POOR / GOOD	POOR	FAIR
T & H & Poll	GOOD	FAIR	GOOD	POOR	GOOD	POOR	GOOD
PRODUCT:	Audio Cassette 9T Comp. Tape Lo-Density Diskettes	Video D-1 Hi Bias Audio Hi-Density Diskettes	4 MByte Diskettes Hi-8mm	Video 3480 Cart. Hi-Bias Audio	Hi-8mm R-DAT D-2 Audio	Hi-8mm	Next Generation

KEY:
- ○ = GOOD — No corrosion or signal loss problems expected
- ○ = FAIR — May be suitable if some signal loss and/or bit errors can be tolerated
- ● = POOR — Unsuitable for storage under this condition

NOTES: *Interim recommendations, based on results of NML and others, as of January, 1991. Does not include possible binder and substrate problems not specific to media type.*

**Battelle Class II Environment*

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Summary
Co-γ-Fe_2O_3 Tape Stability

- Archive Stability: 10 yrs in a dry, controlled environment
  - Retensioning
  - Cleaning
  - Recertification
- Archive requirements are system specific
  - Wide range of system performance
  - User requirements outside recommended controlled environments
  - Distributed Storage Systems require Shipping
  - Anomalous events

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I know that there are going to be some network managers here who would like to throw tomatoes at me at this particular moment ; but even with local area networks and wide-area networks, media will require shipping. And the analogy I always cite is: Remember when they said that we were going to have a paperless office? the same thing here. Media will require shipping; and therefore, we have to be concerned about how it is being shipped.

And we also have to be concerned about anomalies such as fire, water damage as a result of people spilling coffee or whatever, and various other shipping impacts such as DC motors, erasing the tape.

So, we have to be able to do a recovery from these types of anomalies and events. And we have been involved with some tape recovery operations.
That concludes my talk.

(Applause)

DR. KRYDER: We will hold the questions until the discussion. Thank you, Darlene.

Our next speaker is Kazuhiro Okamoto. He obtained his M.S. Degree in Physics from Hokaido University. He has been working at Sony for the past eight years. He is a materials engineer working in the Magnetic Particle Development Group.

The title of his presentation is "Stability of Metal Particles/Metal Particulate Media."

STABILITY OF METAL PARTICLES/METAL PARTICULATE MEDIA

Kazuhiro Okamoto
Sony

MR. OKAMOTO: Thank you. Today, I would like to talk about the study of metal particles and the metal particulate media.